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TELECOMMUNICATIONS SYSTEM AND METHOD FOR LOAD SHARING
WITHIN A CODE DIVISION MULTIPLE ACCESS 2000 NETWORK

BACKGROUND OF THE PRESENT INVENTION

Field of the Invention

The present invention relates generally to code division multiple access (CDMA) networks, and 5 specifically to load sharing within a CDMA2000 network.

Description of Related Art

High Data Rate (HDR) is a technology originally developed for dedicated packet data applications to meet the increasing demand for wireless Internet Protocol (IP) connectivity with high spectral efficiency. Voice transmissions require low data rates, but maintain stringent delay and jitter requirements. Packet data transmissions, on the other hand, typically require bursty high data rates, with less stringent delay and jitter requirements. The HDR principle is to separate high-speed data completely from the voice network, so that the packet data requirements can be fulfilled optimally and independently.

In May 2000, the CDMA Development Group (CDG) accepted HDR as the 1x Evaluation Phase One: Data Only (1xEv DO or 1xEV Phase 1), with minor requirements for improvements. Within the 1xEv DO network, an HDR base station, whether a stand-alone node or integrated within a voice base station, operates on a 1.25 MHZ carrier that is allocated for packet data only.

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The HDR base station further employs a single shared, time division multiplexed (TDM) forward link, where only a single terminal is served at any instance. The forward link throughput rate is shared by all HDR mobile terminals. A mobile terminal selects a serving sector (or cell) of the base station by pointing its Data Rate Control (DRC) to the sector and requesting a forward data rate according to the channel condition (i.e., based on the Carrier to Interference (C/I) ratio of the channel).

A multi-user scheduler at the HDR base station is responsible for granting actual data rates to each mobile terminal. The multi-user scheduler within the HDR base station "fairly" distributes the throughput rate for all mobile terminals pointing their DRC's on the same sector. However, each mobile terminal's data through rate is relative to the number of other mobile terminals and the throughput rate of the other mobile terminals. Since a mobile is blind to the amount of traffic in its sector and adjacent sectors, the

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consequence is that some sectors may be heavily loaded and others may be under loaded.

Previous load sharing methods require the network to select another sector or cell for handoff of one or 5 more subscribers. For example, in PCT Application WO 97/44925, which is hereby incorporated by reference, when a load threshold is exceeded, the network directs a mobile terminal to another cell by channel allocation. As another example, in PCT Application WO 10 96/38011, which is hereby incorporated by reference, mobile terminals are off-loaded to an alternate sector of the base station when a current sector of the base station becomes loaded beyond a loading threshold.

However, in the CDMA2000 network, handoffs to 15 other sectors or other HDR base stations are not initiated by the network. Instead, in the CDMA2000 network, "virtual" handoffs are performed by the mobile terminals themselves. By "virtual", it is meant that when the channel conditions of the current sector 20 selected by the mobile terminal are no longer satisfactory to the mobile terminal, the mobile

terminal itself selects another sector by pointing its DRC towards a new sector. Queued data in the old sector is either retrieved by the new sector or flushed and retransmitted to the new sector. Therefore, there
5 is no current mechanism within the CDMA2000 network for the network to initiate a handoff to another sector or HDR base station based on load conditions.

SUMMARY OF THE INVENTION

10 A telecommunications system and method is disclosed for load sharing within a CDMA2000 network. The queue size of a sector is compared with a predefined threshold. If the queue size exceeds the predefined threshold, one or more mobile terminals
15 having their Data Rate Control (DRC) pointed towards that sector are selected to discontinue using that sector. The network transmits a message to the selected mobile terminals informing the selected mobile terminals that their DRC is no longer valid. In response,
20 the selected mobile terminals stop pointing their DRC towards that sector, which results in an

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interruption of the data sessions of the selected mobile terminals. To continue their data sessions, each of the selected mobile terminals may initiate a "virtual" handoff to another sector.

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BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed invention will be described with reference to the accompanying drawings, which show important sample embodiments of the invention and which 10 are incorporated in the specification hereof by reference, wherein:

FIGURE 1 is a block diagram of a Code Division Multiple Access 2000 (CDMA2000) network implementing a High Data Rate (HDR) base station;

15 FIGURE 2A is a block diagram of an HDR base station serving multiple HDR mobile terminals in accordance with exemplary embodiments of the present invention;

20 FIGURE 2B is a block diagram illustrating an exemplary load sharing process in accordance with embodiments of the present invention;

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FIGURE 2C is a block diagram illustrating the transmission of a message to a mobile terminal after completion of the load sharing process of FIGURE 2B;

5 FIGURE 2D illustrates the setting of each of the fields in the message shown in FIGURE 2C of the drawings;

10 FIGURE 2E is a block diagram illustrating the HDR base station and HDR mobile terminals of FIGURE 2B after the transmission of the message shown in FIGURES 2C and 2D;

FIGURE 3 is a flow chart illustrating exemplary steps for performing the load sharing process in accordance with embodiments of the present invention;

15 FIGURE 4 is a block diagram illustrating a "virtual" handoff after the load sharing process of FIGURES 2B-2E has been completed; and

FIGURE 5 is a flow chart illustrating exemplary steps for performing the "virtual" handoff shown in FIGURE 4 of the drawings.

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DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

The numerous innovative teachings of the present application will be described with particular reference 5 to the exemplary embodiments. However, it should be understood that this class of embodiments provides only a few examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do 10 not necessarily delimit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others.

FIGURE 1 illustrates a Code Division Multiple Access 2000 (CDMA2000) network 100. The CDMA2000 network 100 supports data rates up to 2 Mbps per user and uses higher order modulation schemes and a High Data Rate (HDR) base station 120 to support such high data rates. It should be understood that the base station 120 provides the RF interface (carrier 115) 15 between a mobile terminal 130 and the network 100 via one or more transceivers. The HDR base station 120 provides a separate 1.25 MHZ data only (DO) carrier 115 20

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for HDR applications for each sector 110 (or cell) served by the HDR base station 120. A separate base station or carrier (not shown) provides the voice carrier(s) for voice applications.

5 A HDR mobile terminal 130 may be a DO mobile terminal or a dual mode mobile terminal capable of utilizing both voice services and data services. To engage in a data session, the HDR mobile terminal 130 connects to a DO carrier 115 to use the DO high-speed
10 data service. The data session is controlled by a Packet Data Service Node (PDSN) 160, which routes all data packets between the HDR mobile terminal 130 and the Internet 180. The PDSN 160 has a direct connection to a Packet Control Function (PCF) (not shown), which
15 interfaces with a Base Station Controller (BSC) 150 of the HDR base station 120. The BSC 150 is responsible for operation, maintenance and administration of the HDR base station 120, speech coding, rate adaptation and handling of the radio resources. It should be
20 understood that the BSC 150 may be a separate node or

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may be co-located with one or more HDR base stations 120.

Each HDR base station 120 is shown serving three sectors 115 (or cells). However, it should be understood that each HDR base station 120 may serve only a single cell (referred to as an omni cell). It should also be understood that the network 100 may include multiple HDR base stations 120, each serving one or more sectors 115, with HDR mobile terminals 130 being capable of handing off between sectors 115 of the same HDR base station 120 or sectors 115 of different HDR base stations 120. For each sector 115 (or cell), the HDR base station 120 further employs a single shared, time division multiplexed (TDM) forward link, where only a single HDR mobile terminal 130 is served at any instance. The forward link throughput rate is shared by all HDR mobile terminals 130. A HDR mobile terminal 130 selects a serving sector 115 (or cell) of the HDR base station 120 by pointing its Data Rate Control (DRC) towards the sector 115 and requesting a forward data rate according to the channel conditions

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(i.e., based on the Carrier to Interference (C/I) ratio of the channel).

A multi-user scheduler at the HDR base station 120 is responsible for granting actual data rates to each 5 HDR mobile terminal 130. The multi-user scheduler within the HDR base station 120 "fairly" distributes the throughput rate for all HDR mobile terminals 130 pointing their DRC's towards the same sector 115. However, each HDR mobile terminal's 130 data through 10 rate is relative to the number of other HDR mobile terminals 130 and the throughput rate of the other HDR mobile terminals 130. Since an HDR mobile terminal 130 is blind to the amount of traffic in its sector 115 and adjacent sectors 115, the consequence is that some 15 sectors 115 may be heavily loaded and others may be under loaded.

Reference is now made to FIGURES 2A-2E, which illustrate an exemplary load sharing process for CDMA2000 networks 100, in accordance with embodiments 20 of the present invention. FIGURE 2A shows an HDR base station 120 serving multiple HDR mobile terminals 130

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(MT-A, MT-B, MT-C and MT-D), each having their DRC 135 pointed at one sector 115 (sector 1) of the HDR base station 120. The Default Forward Traffic Channel Medium Access Control (MAC) Protocol of the CDMA2000 network 100 defines the procedures required for the HDR base station 120 to transmit and the HDR mobile terminal 130 to receive the Forward Traffic Channel. 5 This protocol operates in one of three states:

10 (1) Inactive State: In this state, the HDR mobile terminal 130 is not assigned a Forward Traffic Channel.

15 (2) Variable Rate State: In this state, the HDR base station 120 transmits the Forward Traffic Channel to the HDR mobile terminal 130 at a variable rate, as a function of the HDR mobile terminal's DRC 135 value.

20 (3) Fixed Rate State: In this state, the HDR base station 120 transmits the Forward Traffic Channel to the HDR mobile terminal 130 from one particular sector 115, at one particular rate.

25 In the Variable Rate State, the HDR mobile terminal 130 points its DRC 135 towards a sector 115 of the HDR base station 120. The DRC 135 is

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transmitted by the HDR mobile terminal 130 to the HDR base station 120, and includes a DRC cover index and a DRC value. The HDR mobile terminal 130 uses the DRC cover index to specify the transmitting sector 115 preferred by the HDR mobile terminal 130. In the Fixed Rate State, the DRC cover index and the data rate are specified in a message (Fixed Mode Request) sent by the HDR mobile terminal 130 (i.e., in fixed mode, the HDR mobile terminal "points" its DRC using a message instead of the DRC channel transmission used for variable rate mode).

The DRC cover index is either set to "0", which is called the "null cover", or is set to the DRC cover of the preferred sector 115. The DRC value specifies the requested transmission rate for variable rate mode or fixed rate mode. Typically, the HDR mobile terminal 130 sets the DRC value to the maximum desired value that channel conditions permit for the sector 115 at which the HDR mobile terminal 130 is pointing its DRC 135. The maximum throughput rate for an HDR mobile terminal is dependent upon the number of HDR mobile

terminals 130 on that sector 115 and the throughput rate of the other HDR mobile terminals 130 on that sector 115.

Once the HDR mobile terminal 130 has pointed it's
5 DRC 135 towards a particular sector 115 specifying a requested rate, the HDR base station 120 transmits data packets to the HDR mobile terminal 130 on the forward traffic channel at the requested data rate. As discussed above, transmission on the forward traffic
10 channel is time division multiplexed. At any given time, the forward traffic channel is being either transmitted or not; and if it is being transmitted, it is addressed to a single HDR mobile terminal 130. When transmitting on the forward traffic channel, the HDR
15 base station 120 uses a MACIndex associated with a particular HDR mobile terminal 130 to identify the target HDR mobile terminal 130 for the data packets.

Although each HDR mobile terminal 130 specifies its own data rate (DRC value) for forward link
20 transmissions, as shown in FIGURE 2A, if HDR mobile terminals MT-A, MT-B, MT-C and MT-D all point their

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DRC's 135 to sector 1 specifying respective requested rates, and no other sectors 115 (e.g., sectors 2 and 3) of the HDR base station 120 have any HDR mobile terminals 130 pointing their DRC's 135 towards those sectors 115, the result is that sector 1 may become over-loaded with a low average data throughput rate, while sectors 2 and 3 remain under-loaded.

In order to balance the load amongst the sectors 115 of the HDR base station 120 (or sectors 115 of adjacent HDR base stations 120), a load sharing mechanism is needed. FIGURE 2B illustrates such an exemplary load sharing process in accordance with embodiments of the present invention. Each sector 115 of the HDR base station 120 maintains a queue 125 of data packets waiting to be transmitted to HDR mobile terminals 130 pointing their DRC's 135 towards that sector 115. Since the forward traffic channel is time division multiplexed, and a particular HDR mobile terminal 130 receives data packets only in one time slot, each data packet received for a particular HDR mobile terminal 130 must be queued at the HDR base

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station 120 until the time slot assigned to that particular HDR mobile terminal 130 arrives. It should be noted that multiple time slots may be assigned to a particular HDR mobile terminal 130 to make up the 5 forward link channel of the HDR mobile terminal 130, depending upon the requested data rate.

The queue size 128 of each sector 115 is periodically reported to an overhead message handler 155 within the BSC 150. Each vendor may measure the 10 queue size 128 differently based on the way the vendor implements the HDR base station. 120 For example, the queue size 128 may be measured as the number of data packets waiting to be transmitted. Furthermore, the queue size may be based solely on the number of HDR 15 mobile terminals 130 having their DRC 135 pointed towards that sector 115.

The overhead message handler 155 compares the queue size 128 of a particular sector 115 with a predefined threshold 140 for that sector 115. If the 20 threshold 140 for a sector 115 is exceeded, mobile terminal (MT) selection logic 158 analyzes various

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factors to select one or more HDR mobile terminals 130 to discontinue using that sector 115. Such factors may include the queue size for each of the HDR mobile terminals 130, the active set size (i.e., number of other sectors 115 available) of the HDR mobile terminals 130, the requested rate of each of the HDR mobile terminals 130, the order that each of the HDR mobile terminals 130 pointed their DRC 135 towards that sector 115, the C/I ratio experienced by each of the HDR mobile terminals 130 on the forward link, the position of each of the HDR mobile terminals 130 (i.e., the latitude and longitude of each of the HDR mobile terminals 130 as determined by a Global Positioning System (GPS) receiver or other type of positioning system) and the type of HDR mobile terminal 130 (e.g., either DO or dual mode). For example, an HDR mobile terminal 130 connected to the sector 115, but having little or not data queued may be selected first for not pointing its DRC 135 towards the sector 115.

As shown in FIGURES 2B and 2C, the BSC 150 transmits to each of the selected HDR mobile terminals

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130 a message 145 indicating that the selected HDR mobile terminals 130 should stop pointing their DRC 135 towards that sector 115. The message 145 is preferably transmitted on a control channel 118 of the forward 5 link of the HDR base station 120. Each control channel packet contains zero or more control packets for zero or more HDR mobile terminals 130. The control packets include messages 145 that are broadcast to HDR mobile terminals 130 within the sector 115 over the control 10 channel 118.

One type of message 145 included in a control packet is an overhead message. The overhead messages in the CDMA2000 network 100 include the QuickConfig message 145 and the SectorParameters message. The 15 QuickConfig message 145 is used to indicate a change in the contents of the overhead messages and to provide frequently changing information. The SectorParameters message is used to convey sector specific information to the HDR mobile terminals 130.

20 As shown in FIGURE 2D, the QuickConfig message 145 includes a number of fields 148 and a setting 149 for

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each of the fields 148. The Message ID field indicates that the message is a QuickConfig message. The Color Code and Sector ID fields indicate the color code and ID of the sector 115 transmitting the QuickConfig 5 message 145. The Sector Signature field is set to the value of the Sector Signature field of the next SectorParameters message that will be transmitted. Similarly, the Access Signature field is set to the value of the Access Signature parameter from the 10 AccessParameters message, which is transmitted on an Access Channel (not shown) of the forward link. The Redirect field is used to indicate whether or not the network 100 is redirecting all HDR mobile terminals 130 away from the sector 115.

15 The RPC Count field is set to the maximum number of Reverse Power Control (RPC) channels supported by the sector 115. For each RPC Count occurrence (i.e., for each HDR mobile terminal), a DRC Lock field is set to "1" if the network 100 has received a valid DRC 135 20 from the HDR mobile terminal 130 that has been assigned a MACIndex. Each occurrence n of the DRC Lock field is

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associated with MACIndex 64-*n* (e.g., occurrence 1 of this field corresponds to MACIndex 63). Otherwise, the DRC Lock field is set to "0". Similarly, for each RPC Count occurrence *n*, a Forward Traffic Valid field is 5 set to "1" if the forward traffic channel associated with MACIndex 64-*n* is valid. The Reserved field includes six bits and is usually set to zero.

In the example of FIGURES 2C and 2D, the selected HDR mobile terminal 130 is MT-A. The active set of MT-10 A includes more than one sector 115, which may be served by one or more HDR base stations 120 (only one of which is shown). To inform MT-A to not point its DRC 135 towards sector 1, the HDR base station 120 transmits a modified QuickConfig message 145 to MT-A. 15 In the modified QuickConfig message 145, the bit in the DRC Lock field at the RPC count associated with MT-A is set to "0", which instructs MT-A to stop pointing its DRC 135 at sector 1. In addition, instead of setting the Reserved field to zero, the Reserved field is set 20 to the MACIndex of MT-A to distinguish the message from an ordinary fixed rate message.

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Upon the reception of QuickConfig message 145, the HDR mobile terminal 130 (MT-A) specified by the MACIndex in the Reserved field updates its DRC cover index to "0" or "null cover", which indicates that the 5 HDR mobile terminal 130 is not pointing its DRC 135 towards any sector 115. However, from the network perspective, MT-A is still connected to sector 1 until MT-A points its DRC 135 towards another sector 115. Any new incoming data packets for MT-A are queued by 10 the HDR base station 120 and transmitted later by the network 100. Any queued data packets currently within the HDR base station 120 are either flushed and retransmitted later by the network 100 or transferred to a new sector 115 (if MT-A connects to a new sector 15 115).

FIGURE 2E illustrates the status of the HDR mobile terminals MT-A, MT-B, MT-C and MT-D after transmission of the QuickConfig message 145 discussed above in connection with in FIGURES 2C and 2D. As can be seen, 20 MT-B, MT-C and MT-D all still have their DRC's 135 pointed towards sector 1. However, MT-A does not have

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it's DRC 135 pointed towards sector 1. Instead, MT-A's DRC 135 is not pointed towards any sector 115.

Reference is now made to FIGURE 3 of the drawings, where the exemplary steps for performing the load sharing process are shown. Once the queue size of a sector is sent to the Overhead Message Handler in the BSC (step 300), the queue size is compared with a predefined threshold for that sector (step 310). If the queue size is greater than the threshold, one or more HDR mobile terminals are selected to not point their DRC's towards the sector (step 320). All of the selected HDR mobile terminals are sent the modified QuickConfig message with the DRC Lock bit set to "0" (step 330). In response to receiving the modified QuickConfig message, all of the selected HDR mobile terminals update their DRC cover index to "0" (step 340).

If any new HDR mobile terminals point their DRC towards the sector (step 350), these new HDR mobile terminals also receive the QuickConfig message with the DRC Lock bit set to "0" (step 330) and update their DRC

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cover index accordingly (step 340). After the expiration of a timer (step 360), or after a request by the BSC, the HDR base station once again transmits the queue size of the sector to the Overhead Message Handler in the BSC (step 300).

When the selected HDR mobile terminals receive the modified QuickConfig message, the data sessions for those HDR mobile terminals are interrupted (since data packets are no longer transmitted on the forward traffic channel). To continue the data session, the HDR mobile terminal must point its DRC towards another sector of the same HDR base station or a different HDR base station.

As shown in FIGURE 4 of the drawings, MT-A may continue its data session by pointing its DRC 135 towards another sector 115 (here sector 2). Since MT-A is near an edge of sector 1 (which may have been one factor considered when selecting MT-A), the C/I ratio of sector 2 may be at a level sufficient to support a data rate requested by MT-A. To connect to sector 2, MT-A performs a "virtual" handoff by pointing its DRC

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135 towards sector 2 and requesting the maximum data rate needed by MT-A and allowed by sector 2. Queued data in sector 1 is either retrieved by sector 2 or flushed and retransmitted to sector 2 by the PDSN 5 (shown in FIGURE 1).

The exemplary steps for performing such a "virtual" handoff are shown in FIGURE 5. As discussed above, when HDR mobile terminal MT-A receives the QuickConfig message with the DRC Lock bit set to "0" 10 from sector 1 (step 500), MT-A checks the channel conditions of neighboring sectors (step 510). If any of the neighboring sectors has acceptable channel conditions to support the data session for MT-A (step 520), MT-A chooses the sector with the best channel 15 conditions (i.e., sector 2) (step 530) and points its DRC towards that sector (step 540). As discussed above, queued data in the old sector is either retrieved by the new sector or flushed and retransmitted to the new sector. However, if no sector 20 has acceptable channel conditions (step 520), MT-A

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remains connected to sector 1 by once again pointing it's DRC towards sector 1 (step 550).

Since HDR mobile terminals select the sector, even if the modified QuickConfig message is sent to the HDR mobile terminal, if the HDR mobile terminal does not update it's DRC cover index to "0", the HDR mobile terminal remains connected to that sector. The above described load sharing process endeavors to increase the average throughput rate on a sector. Therefore, if MT-A remain connected to sector 1, the throughput rate experience by MT-A may be lower than the requested throughput rate.

As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a wide range of applications. Accordingly, the scope of patented subject matter should not be limited to any of the specific exemplary teachings discussed, but is instead defined by the following claims.